Coastal Observations, Mechanisms, and Predictions Across Systems and Scales—Field, Measurements, and Experiments (COMPASS-FME)

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COMPASS Coastal Observations, Mechanisms, and Predictions Across Systems and Scales | FIELD, MEASUREMENTS, AND EXPERIMENTS

Improving fundamental scientific understanding, model representation, and predictive capacity of coastal systems

Coastal regions—defined as zones where the land margin meets large, open water bodies—are home to high proportions of global population, trade, infrastructure, and biological productivity. The importance of these critical zones to understanding the integrated Earth system continues to grow, especially as extreme events increasingly threaten coastal energy, economic, ecosystem, and national security assets. Coastal systems are dynamic and, in many cases, are rapidly changing due to a wide range of natural and anthropogenic influences, such as sea level rise, hydrologic intensification, land-use and land-cover change, and urbanization.

As critical as coastal zones are to the planet, much of the science needed to understand and predict their behavior—from molecular processes to global scales—is limited by insufficient mechanistic data and inadequate quantitative and predictive tools. Further, processes and interactions in coastal regions function at different temporal and spatial scales, often across compressed spatial zones, making them difficult to represent in Earth system models (ESMs).

New national priorities for enhancing Earth system predictability reinforce the importance of taking on these challenges. COMPASS-FME aims to improve the reliability and predictive power of ESMs by combining advanced computation with focused observational data to represent the complexity of coastal systems more accurately. Supported by the U.S. Department of Energy's (DOE) Biological and Environmental Research (BER) program, the project's initial activities focus on developing a predictive understanding of the causes, mechanisms, and consequences of the shift between aerobic and anaerobic conditions at both saltwater and freshwater terrestrial–aquatic interfaces (TAIs).

Fundamental Mechanisms and Processes

Predicting how coastal systems respond to extreme events and long-term changes requires new mechanistic studies of interacting processes, system connections that operate through soil-microbe-vegetation subsystems, and impacts of disturbances. COMPASS-FME research is advancing the mechanistic understanding and representation of coastal ecosystem structure and function in response to hydrologic disturbances in the Chesapeake Bay and Western Lake Erie Basin. Initially, the project focuses on disturbance events arising from hydrologic cycle intensification and characterized by more variable and intense precipitation patterns, flooding events, storm surges, and seiches. Measurements, experiments, and models are directly linked to improve the predictive understanding of these important systems.

Key COMPASS-FME Science Questions

The COMPASS-FME project seeks to advance a scalable, predictive understanding of the fundamental biogeochemical processes, ecological structure, and ecosystem dynamics that distinguish coastal TAIs from purely terrestrial or aquatic systems.

Related research tasks aim to answer two overarching long-term science questions:

- What fundamental mechanisms control the structure, function, and evolution of coastal TAIs?
- How do these fundamental mechanisms interact across spatial scales, and what interactions are most important to improving predictive models?

Studying sites in two distinct regions, the Chesapeake Bay (top) and the Western Lake Erie Basin (bottom), provides COMPASS-FME with an interesting contrast of saltwater and freshwater coasts that allows researchers to differentiate the impacts of inundation and coastal water chemistries in two nationally important coastal systems.

To develop a mechanistic understanding of the transformations and exchanges of carbon, nutrients, and redox-active elements across coastal TAIs, field observations and lab- and field-based experiments are used to improve fundamental representation in models and test specific hypotheses.

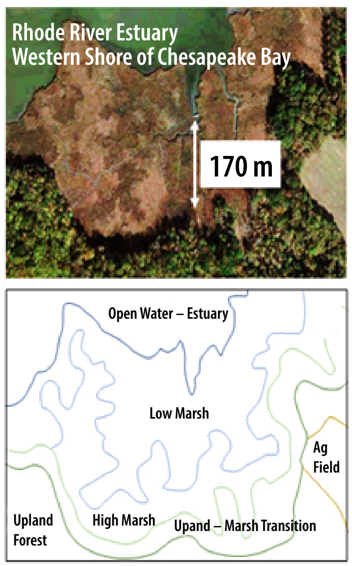
Three types of activities provide spatial, temporal, and mechanistic information about these coastal interfaces:

- **EXCHANGE (Exploration of Coastal Hydro-biogeochemistry Across a Network of Gradients and Experiments):** Sampling kits deployed to a network of external collaborators are capturing baseline spatial heterogeneity in hydrobiogeochemical properties in the Great Lakes and Mid-Atlantic regions.

- **Fixed and Mobile Synoptic Sites:** Sites established in both regions help characterize how ecosystem structure and function vary with physicochemical conditions. Mobile sites are being visited in a series of campaigns designed to make measurements through important inundation events.
- **Experiments:** Lab incubations of soil and sediment cores, batch experiments, and soil transplant experiments in the field are assessing the effects of inundation (with and without salinization) on biogeochemical cycles at the sites.

Process Coupling Across Scales

Projecting the evolution of interconnected coastal systems requires an integrated modeling approach that leverages improved mechanistic understanding and extends it across scales to simulate future changes along the land-river-coast and atmosphere-surface-subsurface continuums while accounting for key natural processes and human influences. COMPASS-FME is building on previous work by DOE national laboratories and the university research community to establish process-rich, integrated modeling capabilities that can be enhanced, coupled, and applied to address important science questions.



Coastal TAI from the Rhode River estuary showing macro- and microtopography and land-cover categories that occur across a 170-meter transect. National Wildlife Refuge, Virginia.

Using multiscale measurements and additional data sources from remote sensing platforms in combination with machine learning–based algorithms, COMPASS-FME will develop new predictive understanding of how dynamics at fine spatial scales influence coastal TAI structure and function at larger spatial scales. The approach includes data and models in a nested hierarchy of scales, providing a new capability to predict the dynamics of coastal TAIs at scales relevant to the land surface component of a high-resolution ESM.

The following three types of activities integrate the knowledge gained as field observations and experiments proceed into a predictive framework.

- **Coupled Process Modeling and Analyses:** Soil, water, and plant interactions will be represented in process-resolving TAI models to evaluate how mechanistic TAI models that integrate this continuum of TAI components improve the predictions of carbon and nitrogen transformations and fluxes.
- **Data-Model Integration across Scales:** The scale dependency of hydrology, vegetation, and soil biogeochemistry will be identified by comparing observations, fine-scale modeling results, and gridded model representations across multiple demonstration grid cells spanning a range of coastal TAI types.
- **Predicting Future Disturbance Impacts:** A large-scale field manipulation within the Chesapeake Bay region, "TEMPEST," will determine the mechanisms and impacts of seawater inundation from a storm surge versus freshwater inundation. Models that include vegetation, hydrology, and soil processes will be developed for coastal TAI systems, evaluated against data from the field manipulation, and applied to understand the impacts of disturbances on ecosystem structure and function and to identify state-change thresholds.

COMPASS-FME Collaboration

Led by Pacific Northwest National Laboratory, the COMPASS-FME project is a collaborative effort that includes scientists at Argonne National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, the University of Toledo, Heidelberg University, and the Smithsonian Environmental Research Center. COMPASS-FME builds on current BER modeling investments in the Mid-Atlantic by expanding ongoing research in the Chesapeake Bay and Great Lakes and providing essential biogeochemical and ecological data to support long-term model improvement for these regions.

A companion program to COMPASS-FME, COMPASS-Great Lakes Modeling, conducts research to improve regional ESMs to understand climate feedbacks in the Great Lakes region.

All COMPASS-FME data are available at data.ess-dive.lbl.gov/portals/compass. These data include automated data collected from in situ sensors located in soil, waters, and plants; large campaign-based fieldwork collections; community science efforts (coastal.exchange@pnnl.gov); synthesis and meta-analysis datasets compiled from published and unpublished studies; and discrete datasets generated from chemical, biochemical, and molecular characterizations of soil, water, and microbial or plant samples. BER provides funding to leverage the COMPASS investment through regular Funding Opportunity Announcements posted at www.grants.gov.

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